EXP-47
August 9, 1973

ACCELERATOR EXPERIMENT: Booster Injection Alignment

Dates: 12, 13 and 31 July 1973

## History

The fact of early beam loss in the Booster occurring at or near the injection girder has been known for sometime. The low efficiency of multiturn injection has been a continuing problem. The difficulty of capturing low amplitude betatron oscillations in multiturn injection and the beam decay at large betatron oscillations are other problems that must be understood before efficient multiturn injection into the Booster can be accomplished.

The past two months have seen a more directed effort at understanding these problems. On June 4 a measurement of beam loss as a function of betatron oscillation in the single-turn injection was made. An attempt to minimize betatron oscillation at injection by moving the septum and inflector tie point out was made on June 8. A position 1½ turns out of the alignment screw and then further out another 1½ turns from the initial positron were tried. Evidence of beam scraping on injection was observed at the larger one so that the position was returned to the 1½ turn position. On June 11, 13 and 14 observations of beam loss were made. Beam loss was found to be sensitive to the horizontal and vertical bumps of the present tuneup. An apparent septum thickness of $\sim$4mm was reported. Septum thickness should be something more related to the thin wires of the inflector. The septum entrance was moved in 3/4 of a turn on the alignment screw.

June 18 saw more betatron amplitude measurements and a short look at the effects of the inflector on beam loss. Beam loss as a function of betatron amplitudes was done again on July 2. Finally, we report the more recent set of experiments of the past several weeks.

## Experimental Technique

It was decided early in July to spend some of the next available booster study time trying to understand injection conditions and the measurements that can be made.

Figure 1 shows a simplified sketch of the injection area. Alignment points of the septum (S2) and inflector are one at each end with a common adjustable tie point between the two. Positions of the two wire scanners on the injection girder and the two halves of the orbit bump magnets are shown relative to the magnetic septum (S2) and the electrostatic inflector. L01 position detector of the closed-orbit data collection system is also at the position of wire 10.

Besides the normal closed orbit measurements made on the standard position monitors, the orbit can be measured with the wires. Three types of measurements were found useful. The first, called extinction data, just involves reading the wire position at the outer edges of the region where coasting beam is killed by the wire. The second measurement is a scan by the wire and a scope sweep at each wire position providing a two dimentional picture of beam position as a function of time. One can see the individual turns in the booster by this method. These two wires can also scan the injected beam to give its position and angle. Figure 2 shows an example of an extinction curve and wire scope sweep measurement.

## Experiment

Wire 9 is just after the inflector so that the "apparent" septum thickness appears on a multiturn scan of wire 9. The "apparent" septum thickness is defined as the distance between the inside of the injected beam to the outside of the first turn around the booster. This distance shows how close the turns can be packed into the booster aperture. Efficient filling of the aperture with low beam loss requires a small "apparent" septum thickness. The injected beam should come out parallel to the closed orbit and be tuned to be as close to the inflector wires as possible. The closed orbit should be parallel to the inflector on the inside and decay in by orbit bump magnets to let the beam just skim the inside of the inflector on the second turn around (tune of one half). Even if the tune is not one half, it should be possible to get a very small "apparent" septum thickness by the present definition.

Measurements of the closed orbit around the booster have, for sometime, been showing a negative angle across the injection area. This effect even extends to some extent to high-field orbits. Magnet alignment for high-field orbits have not included the injection area in the past. This problem is being looked into to be corrected at some later date. A measurement of the orbit position at S24 and S01 allow the determination of the angle at the injection long-straight. Under the nominal running tuneup of July 13 this angle was measured to be about -1.3mr. Extinction data from wires 9 and 10 gave an angle of about -2mr. A negative angle is towards the center of the booster ring. After some tuneup this was reduced to ∿-.7mr.

If the orbit bump is off, the injected beam has a straight path between wires 9 and 10, so that the angle of the injected beam can be measured. Even after the tuning that reduced the closed orbit angle to -.7mr, the injection angle still measured -2.7mr. This indication of a negative angle of injection to orbit was verified by looking at the position of the turns on wire 10 to check the phase of the betatron oscillations. Knowing the horizontal tune one can easily see if injection is occurring with a positive or negative angle. In fact, during later running, the tune was shifted to 2/3 to make the phase checking easier. A tune of 2/3 makes the zero angle injected beam have the first and second turns come at the same radius. A positive angle makes the first turn have a larger beam radius than the second and vice versa for a negative angle.

Using the wires to see the results, the machine was tuned to a good multiturn condition. Under these conditions the "thick" septum remained and the early loss was observed. The first turn loss has been seen in the past and was again observed to occur on the injection girder. A deliberate attempt to scrape beam on the septum during the first turn produced not a thinner septum but what might be spray between the first turn and the position of the injected beam.

On July 25th a radiation survey of the injection area was done. Figure 3 shows two curves superimposed on a mechanical layout of the injection area. The curves are on the side of the septum and inflector that they were measured on. The surveys are consistent with first turn loss on the septum 2/3 of the way downstream, or scraping of the injected beam.

The septum and inflector are tied together to one radial adjustment screw at the junction between them. A movement of four turns (1.27 mm/turn) out produced more spray and a "thicker" septum, the wrong way. Four more positions of the alignment screw were tried. (2, 4, 6 and 8 turns in.) In Figure 4 the distance of the wire center to the outer edge of the first turn is shown by the X and the observed septum "thickness" by an 0 plotted against the septum-inflector position in turns of the alignment screw. As the position was moved in, a decrease in the septum "thickness" was observed and at extreme "in" positions the first turn beam is seen to be "pushed" in by the septum. The position was returned to a net change of four turns in from the starting position. The "thickness" of the septum on returning to the four turns (5mm) in position is shown by the triangle. The fact that it appeared even smaller than the first time at that position probably has more to do with better tuning of the injection elements than non-reproduceable septum positioning. After each move, injection tuning is required to see the effect of the move.

If the outer edge of the first turn is taken as a measure of the septum-inflector position, the position returned to is approximately $\sim$18mm from the wire center.

In Figure 5 is shown a plot of some data taken earlier (July 2) of beam life time as a function of kicker-induced betatron oscillations for beam remaining after first turn, 50μs, and 2.5ms. The vertical scale is the toroid reading in volts and the horizontal is the half-width of the outside extent of beam oscillations as seen on the wire scanners. This is a simple, but not very accurate, measurement of the observed oscillations; however, it gives a rough picture of the situation. The horizontal-dashed line is the injection level and the vertical-dashed line is the recent multiturn running level. Observe where the septum-inflector has been moved to on that scale.

## Conclusion

The original position of the septum inflector was with the downstream inflector in too far. The original apparent "thick" septum was due to this misalignment.

The spray that was observed when a close tuning was made was the result of beam going through the wires of the inflector. This position of the downstream end of the inflector might also have something to do with the decay of the larger betatron oscillations as seen in the last figure.

The position of the septum inflector is now (July 31) felt to have the inflector tangent to the orbit as it should be, but in too far. Both ends of the inflector need to be moved out to increase the aperture.

E. Gray

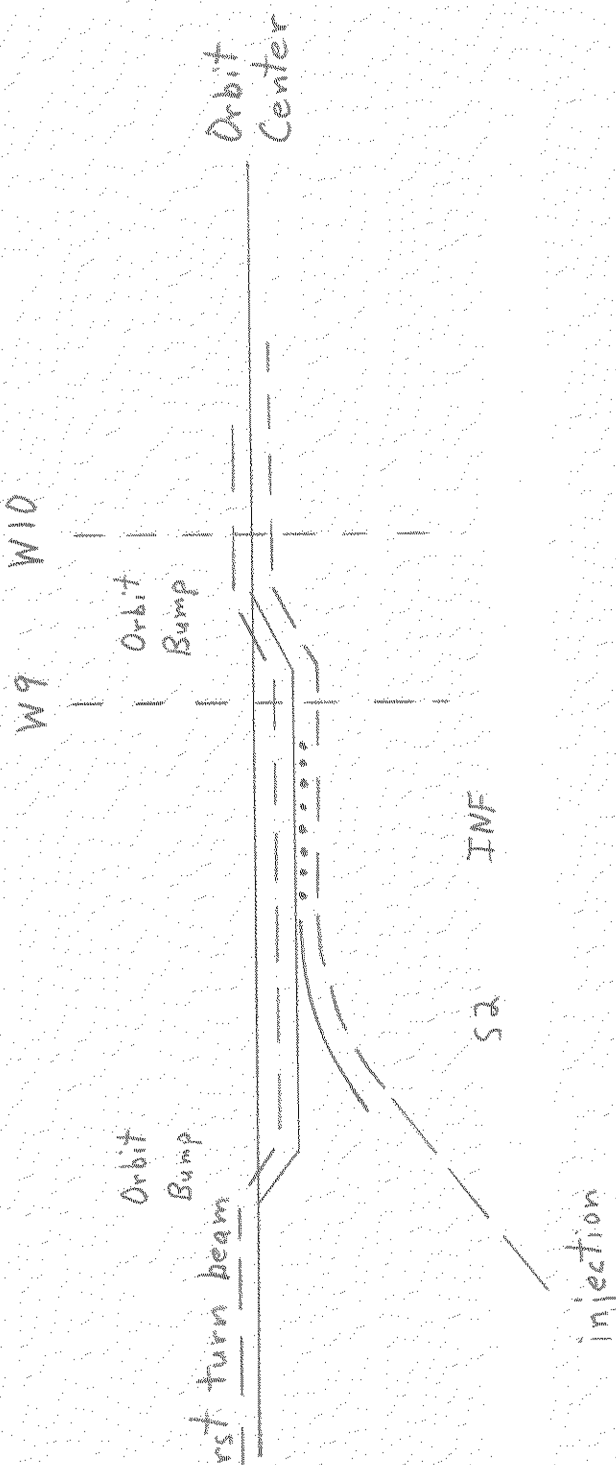
Orbit
Center
W10
W9
Orbit
Bump
INF
S2
Orbit
Bump
First turn beam
Injection
beam

Figure 1

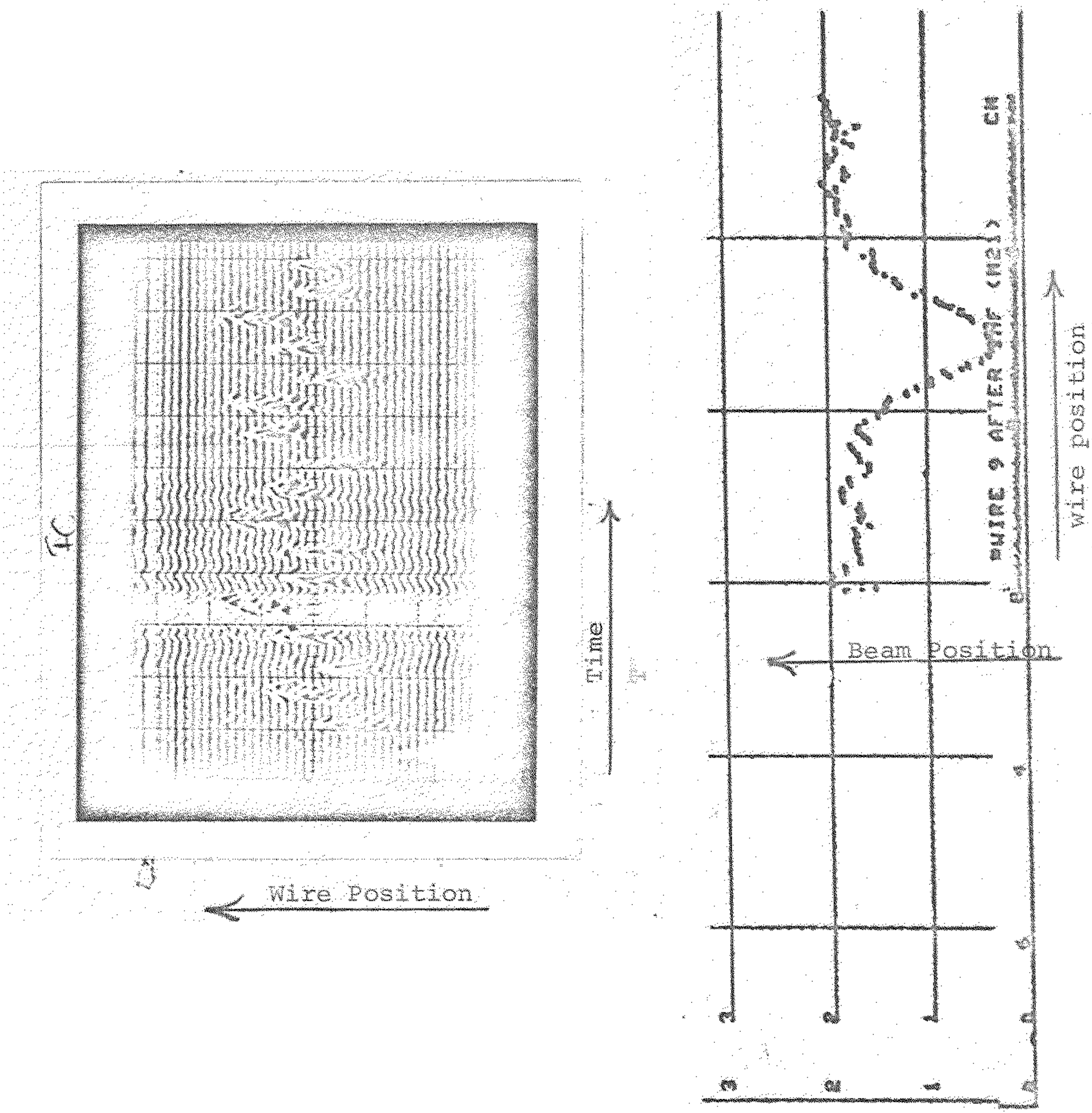


Figure 2

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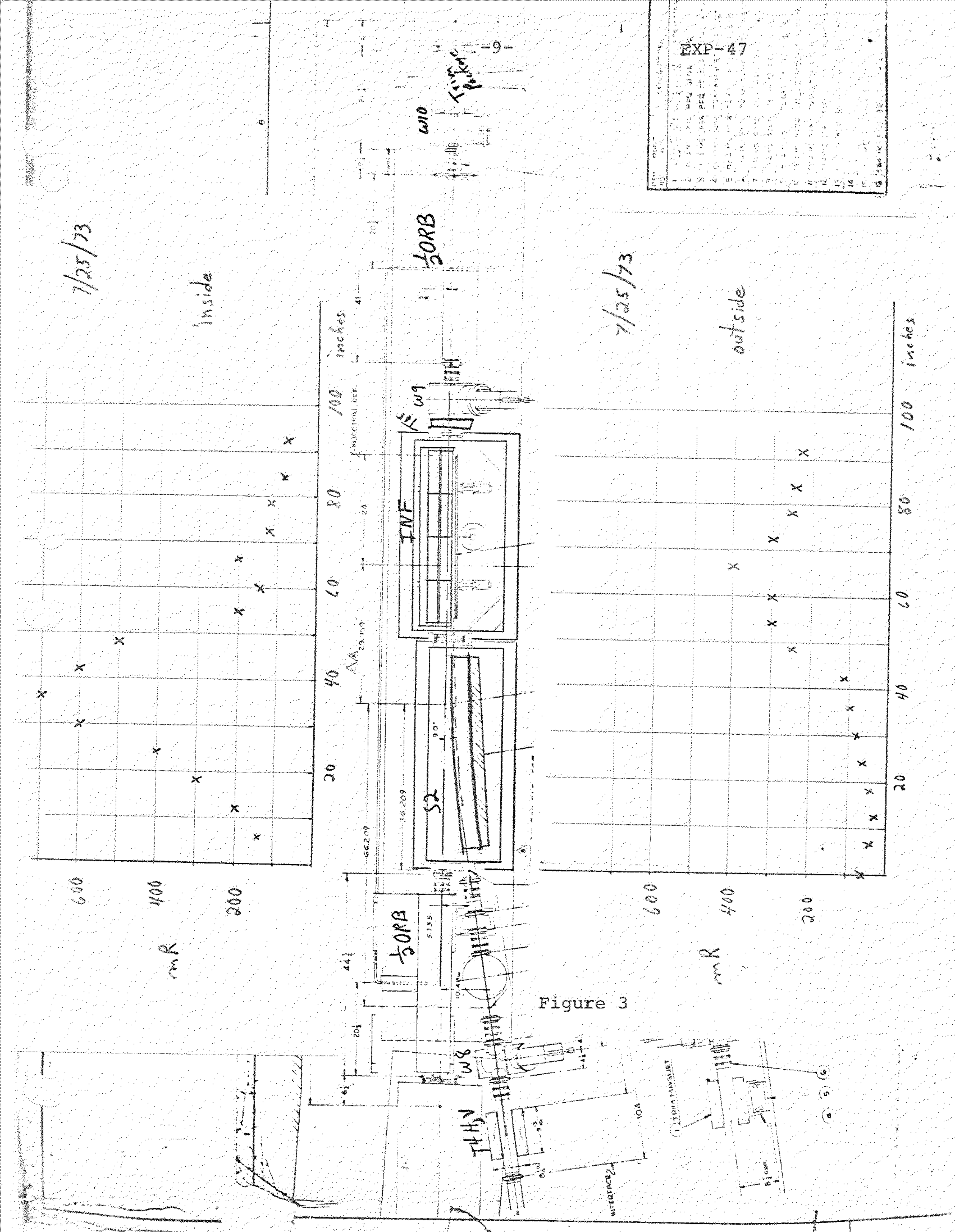


Figure 3

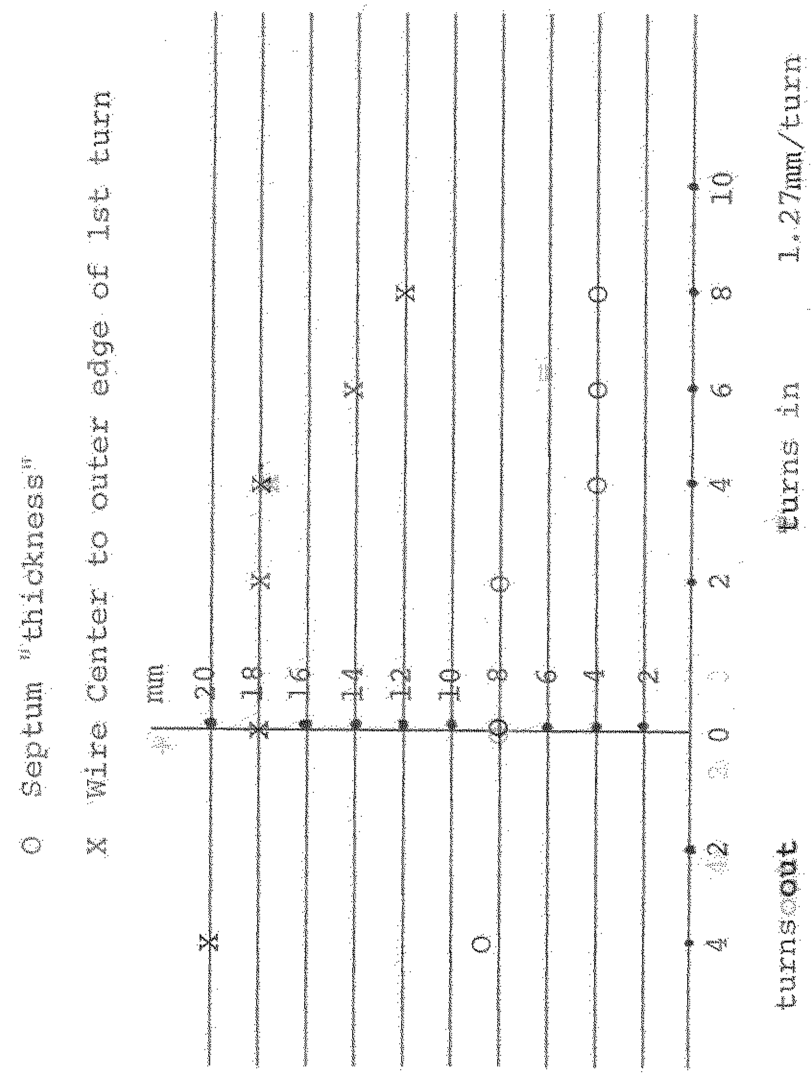
O Septum "thickness"
X Wire Center to outer edge of 1st turn
mm
20
18
16
14
12
10
8
6
4
2
0
4
2
2
4
6
8
10
turns out
turns in
1.27mm/turn

Figure 4

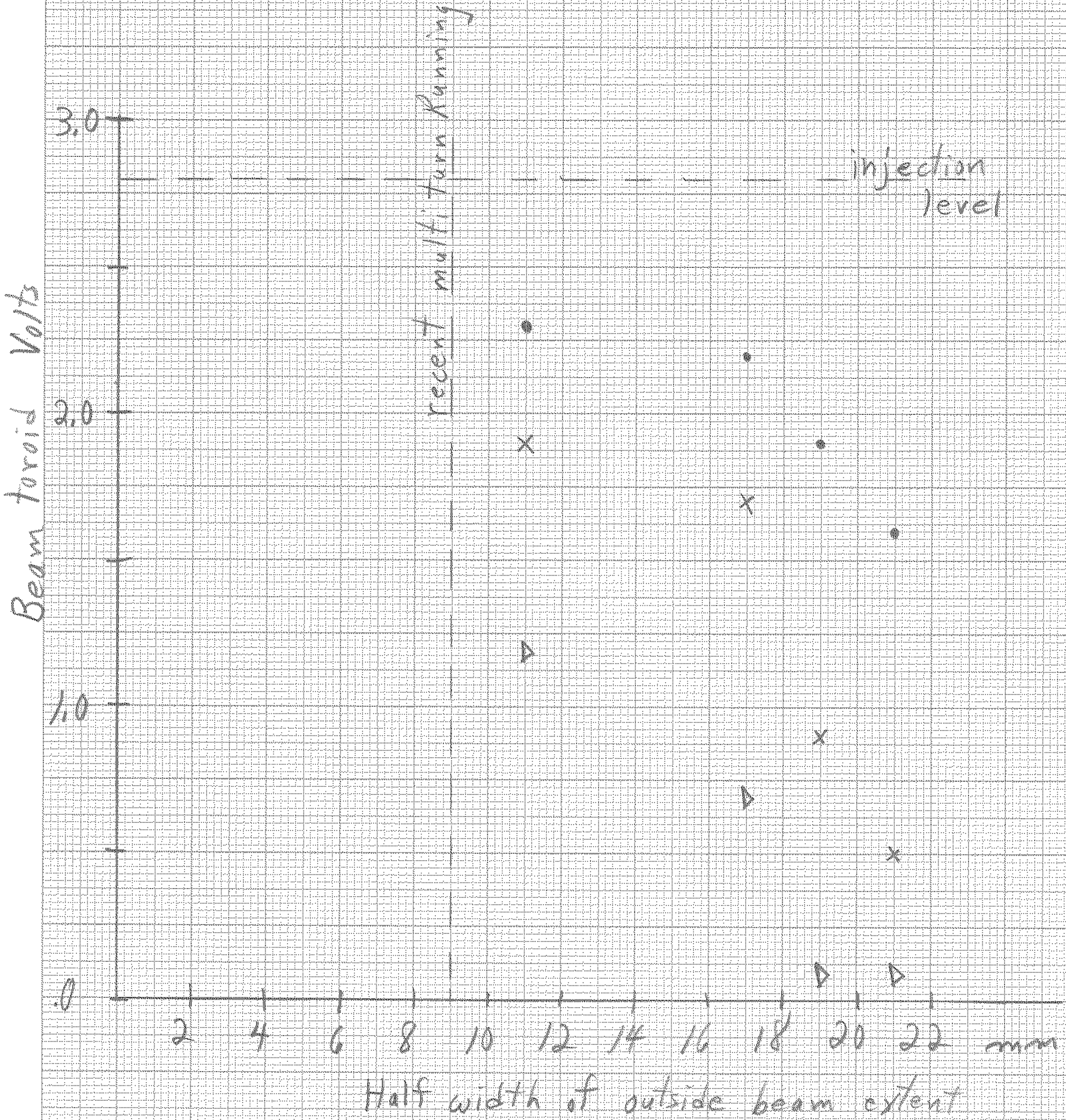
recent multi turn Running
injection level
Beam toroid Volts
3.0
2.0
1.0
0
2
4
6
8
10
12
14
16
18
20
22
mm
Half width of outside beam extent

Figure 5